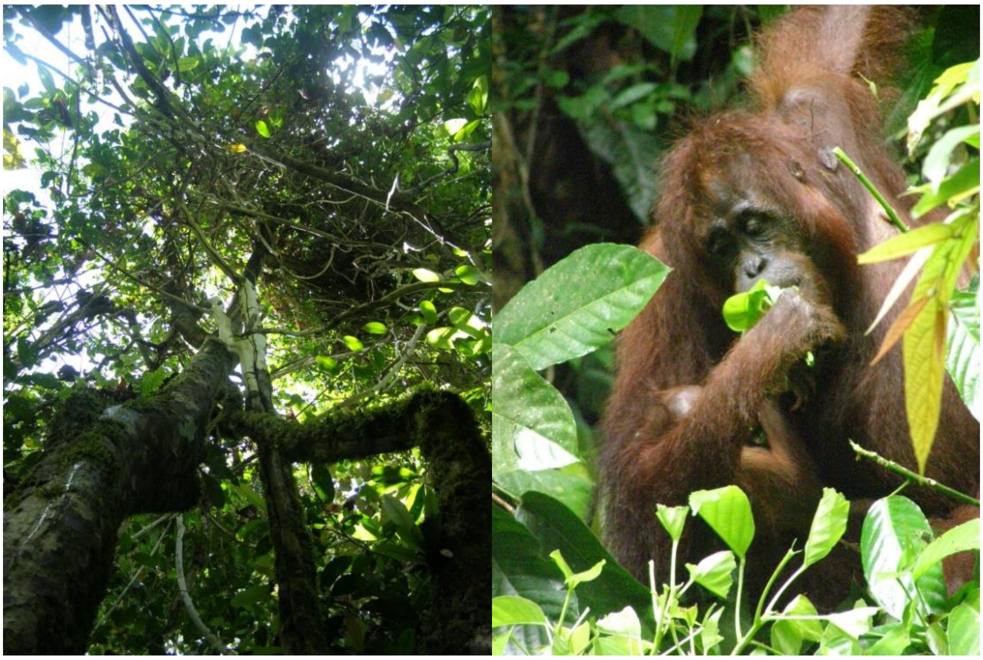
<u>Seasonal Variations in the Dietary Composition and Diversity of the Bornean Orangutan (*Pongo Pygmaeus Morio*)</u>



Images: *Lophopyxis maingayi* and *Pongo pygmaeus*

Rachel Henson

Degree Scheme: B.Sc. Biology

Student Number: 0516337

Vocational Supervisor: Dr. Benoit Goossens

Project Supervisor: Dr. Ian Vaughan

Cardiff University

School of Biosciences

Professional Training Year Project

Word Count: 5,777

Contents

Tables

Figures

Abbreviations

LKWS – Lower Kinabatangan Wildlife Sanctuary

PCA – Principal Components Analysis

Professional Training Year at Danau Girang Field Centre

My primary role was to facilitate the daily running of Danau Girang Field Centre. This involved acting as a research assistant, giving guided walks in the forest, identifying flora and fauna of interest to visitors, small mammal trapping, mist netting of birds, bat capture, spotting and identifying wildlife on the river, and offering advice and local information.

The placement gave me the opportunity to work with people studying microbiology, animal behaviour, conservation and population genetics, water quality, conservation biology, as well as people working in zoos, charities, photographers and journalists. I assisted a three month study on the abundance of nocturnal primates involving night walks, point sampling, observing the design and helping construction of slow loris traps. I learnt how to use a ‘Big Shot’ catapult to accurately fire ropes high into trees to hoist and check the traps.

I witnessed the challenges associated with running a field centre in a remote location: Transporting fuel, maintaining a generator, obtaining drinking water, organising perishable food, defending property from wildlife, and elephant fence construction. I helped to prepare for the needs of each visitor, maintain buildings and learnt to work in a flooded environment during the rainy season. The PTY students were responsible for trail maintenance and preservation of four botanical plots. After the rainy season many trees required new labels; this developed the ability for plant identification. I also conducted a primate survey in April to contribute data for a possible long-term study.

The second-year Cardiff University field course arrived in the last month of my placement. I helped prepare the centre to accommodate over forty people, coordinated the primate survey, assisted the Cardiff University staff and gave a presentation on jungle life to the students.

I started a newsletter to publicise the field centre. I wrote, compiled and edited the publication, gaining input from available sources. Nine editions of The Jungle Times were distributed by email and made available for download online. During the placement, I also wrote a press release about a group of school children who visited to collect rubbish on the Kinabatangan River. The release was published in its entirety in a national newspaper, The Borneo Post.

I worked closely with a local NGO, Hutan, and conducted an investigation about orang-utan feeding behaviour using data collected by field assistants in a nearby village. I am now working on a scientific paper to be published next year. My data analysis skills have increased enormously as a result of this project. I had many opportunities to work with the NGO in the field, learning data collection techniques, assisting transect surveys and learning about conservation issues first-hand, including the effects of palm-oil industry on the environment and local communities, and reforestation programmes.

I volunteered to help organise and run environmental education activities at the Kinabalu International School bazaar in Kota Kinabalu. This was led by the Hutan Education Team, who we worked with on a number of occasions. I studied Bahasa Malaysia throughout the year, which enabled better communication with staff, colleagues and local people. I translated several educational posters from Bahasa Malaysia to English.

Abstract

The Bornean orang-utan, *Pongo pygmaeus*, is present in several populations in Sabah, Malaysia. Forests in the Lower Kinabatangan Wildlife Sanctuary are highly fragmented, yet orang-utans inhabit the area at a high density. Studying feeding behaviour can contribute to a better understanding of the sort of habitats required to sustain wild orang-utan populations, as well as contributing to knowledge of other aspects of orang-utan behaviour such as social distribution and time budgets. The aims of this study are to give an overview of the diet of one population found in Lot 2 of the wildlife sanctuary, identify the major dietary components and investigate seasonality and inter-year differences in diet composition and diversity. A wide variety of food items were recorded and the major trends identified. *Ficus* is the major component of the diet throughout the year in all years, but other food items are essential to fill in when preferred foods are absent. Fruits were chosen above other plant parts, such as bark and leaves, although these were consumed when fruits were not available. Diet composition was found to be subject to seasonal changes and diversity was found to vary between years. This study highlights the importance of managing orang-utan habitats to maintain a diverse array of food items in order to optimise their chances of survival in the long-term.

Keywords: Orang-utan; Feeding Behaviour; Diet; *Ficus*; Sabah

Word Count: 5,263

Introduction

The Bornean orang-utan (*Pongo pygmaeus*) is endemic to the island of Borneo, where three subspecies are found: *Pongo pygmaeus morio, Pongo pygmaeus wurmbii* and *Pongo pygmaeus pygmaeus*. The subspecies found in Sabah is *Pongo pygmaeus morio*. A 2008 study suggests that 54,000 orang-utans currently live on Borneo (Wich *et al.*, 2008). 11,000 orang-utans are estimated to live in Sabah, with a *Pongo pygmaeus morio* population of 1,100 individuals living in the Lower Kinabatangan floodplain (Ancrenaz *et al.*, 2004). Ten sympatric species of primate are known to inhabit the area, eight of which are diurnal, including two species of macaque, three species of langur, the proboscis monkey (*Nasalis larvatus*) and the Bornean gibbon (*Hylobates muelleri*) and the orang-utan.

Sabah has a tropical climate and experiences a wet and a dry season each year. The dry season runs roughly from March until November, and the wet season between December and February, during which time an increase in rainfall is experienced.

Orang-utans spend a large portion of the day foraging and feeding. On average, 40% of the day is spent resting and 40% feeding (Ancrenaz *et al.*, 2007) within the active period. The start time for the active period of an orang-utan is defined as either leaving the nest or the moment behaviour other than resting is observed in the nest. The active period ends when the orang-utan ceases activity in the nest at night (Morrogh-Bernard *et al.*, 2002). Orang-utans create a nest each evening to rest in until the following morning, although sometimes a day nest is built to rest in during the day (Prasetyo *et al.*, 2009). Orang-utans feed mostly on fruit (Lackman and Ancrenaz, 2009; Russon *et al.*, 2009) and fall back on bark and leaves to supplement their diet (Knott, 1998). Seasonality may cause feeding differences within the year, but fluctuations in fruit availability between years may also affect the diet. The diet of a Sumatran orang-utan (*Pongo abelii*) population in Ketambe, Sumatra, was not found to be significantly influenced by fruit availability fluctuations although 67.5% of the diet was found to consist of fruit (Wich *et al.*, 2006).Masting events occur in Borneo every 2-10 years (Wich *et al.*, 2006). During these periods, trees of different genera fruit in unison. Knott (1998) studied Bornean orang-utan behaviour in mast and non-mast periods and found that when fruits were not so readily available in the non-masting period, orang-utans fed on cambium, a constituent of bark, and leaves more often. During the masting period orang-utans fed almost completely on fruit. Fruits contain more calories than bark or leaves (Knott, 1998) and so are preferred food sources for high energy intake. No masting event was recorded in the Kinabatangan between 1999 and 2008, the study period for this investigation, so no significant variation in diet between years would be expected.

The forests of Sabah were subjected to intensive logging in the 1950s to support timber production demands and large areas of land continue to be used for agriculture today, most notably for oil palm production. This is an important source of income for Malaysia and Indonesia, the only countries still home to the two species of orang-utan, *Pongo pygmaeus* and *Pongo abelii.* Forests in the Kinabatangan are highly fragmented as oil palm plantations encroach into remaining forest reserves. The main threats to the orang-utan are deforestation and hunting. Orang-utan hunting is uncommon in Sabah, but habitat loss and degradation is a threat to all remaining populations of *P. pygmaeus*. It is therefore important to clearly identify the requirements to sustain wildlife populations in a rapidly changing environment. Russon *et al.* (2009) found between 21 and 221 genera amongst the diets of orang-utans studied in sites across Borneo and Sumatra, indicating that orang-utans have diverse feeding preferences. 122 genera were identified in the diet of the Kinabatangan population, which is much higher than the figure for Danum Valley (58 genera) and Ulu Segama (62 genera) which are also in Sabah. Neither Ulu Segama nor Danum Valley have been subjected to intensive logging. Despite inhabiting an area of degraded forest, orang-utan density in the Kinabatangan is higher, 5 ind/km^2 (Ancrenaz *et al.*, 2004), than in other areas of Borneo, 1-2 ind/km^2 (Rijksen and Meijaard, 1999). Secondary forest is able to sustain healthy populations of orang-utans and a clearer indication of the key species involved in upholding these populations would be useful in maintaining their presence in the wild.

As well as conservation implications of studying the diet of an animal, information about feeding behaviour is necessary to better understand other, closely linked, behaviours such as spatial distribution. Orang-utans are semi-solitary animals and, other than consorting couples and mother/offspring units, only tend to congregate in areas rich in ripe fruit (Strier, 2006). The diet of an individual is also likely to affect its other behaviours according to its energy intake. Higher quality diets provide more energy for other activities, such as moving. The purpose of this study was to add to existing knowledge about the species.

The aims of this investigation were:

- To provide a dietary overview and identify key items in the diet of the Kinabatangan orang-utan population with regard to sustaining the population in the long-term
- To identify and describe any seasonal and inter-year variations in diet composition and diversity

From these aims and background research, the following hypotheses were constructed:

- There is significant variation in diversity of the diet throughout the year
- There is significant variation in diversity of the diet between years
- There is significant variation in diet composition throughout the year
- There is significant variation in diet composition between years

Important tree species were identified and conclusions about seasonal and inter-year variation in composition and diversity of the orang-utan diet in the Kinabatangan were drawn and can be found at the end of this report.

Map of Borneo

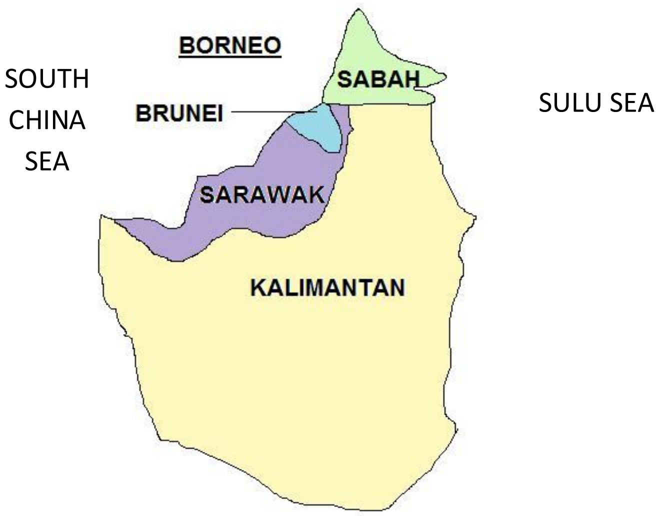


Figure 1. A map of Borneo, showing the Malaysian state of Sabah.

Lower Kinabatangan Wildlife Sanctuary

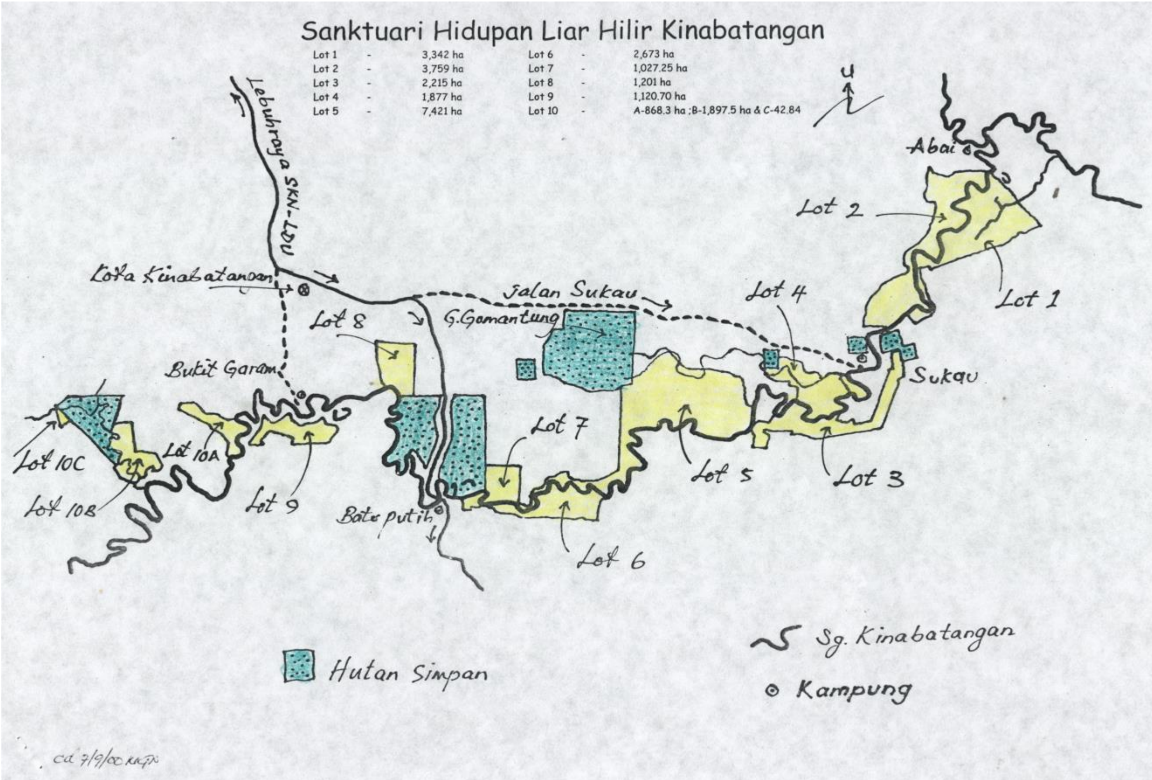


Figure 2. A map of the Lower Kinabatangan Wildlife Sanctuary. The study site is situated in Lot 2, to the east of Sukau. The site lies on the north bank of the Kinabatangan River (Sg. Kinabatangan), illustrated with a thick, black line. Yellow, shaded areas indicate protected areas. Danau Girang Field Centre, where the data was processed, is in Lot 6. (Ancrenaz *et al.*, 2006)

Materials and Methods

Data Collection in the Field

Behavioural observations were made on orang-utans in a study site (118°8'E, 5°32'N) in Lot 2 of the Lower Kinabatangan Wildlife Sanctuary, Sabah, Borneo, Malaysia. The study site is accessible by boat from the village of Sukau. The wildlife sanctuary consists of 26,000 ha land gazetted as a protected area in 2005 (Ancrenaz, 2006) and lies on a floodplain bordering the Kinabatangan River that flows 560 km through eastern Sabah and is subject to seasonal flooding. The land lies low at 10-20 m above sea level, with peaks reaching 50 m above sea level (Marshall *et al.*, 2009). The forest in this area is secondary forest, currently fragmented by obstacles such as oil palm plantations, and consists of mixed lowland dipterocarp forest and swamp forest.

The data used was collected over a period of ten years, 1999 – 2008. It was collected by field researchers working for the Kinabatangan Orangutan Conservation Project. Teams of two researchers looked for orang-utans within the study site, locating the animals by sight, sound or evidence such as broken branches and discarded food items. When found, if the animal was not distressed, it was followed until being subsequently lost. Many of the animals were frequently sighted in the study area, but non-habituated orang-utans were not followed if signs of prolonged distress were shown. When following an orang-utan the team arrived at 0530 to begin recording data at 0600. Data collection ceased at 1830. Scans were taken every three minutes to record the behaviour of focal orang-utans. Data collection was conducted in accordance with the methods outlined in Orang-utan Data Collection Standardisation (Morrogh-Bernard *et al.*, 2002). When a female orang-utan was encountered with offspring, the mother was observed as the focal animal.

The information recorded included the date, time, activity of orang-utan (feeding, moving, nesting, resting, socialising or difficult to see), plant species consumed (scientific name, local name and family), plant part consumed, tree height, weather and additional remarks. Food items were identified by sight and parts were identified as fruits, leaves, bark and other for analysis. The raw scans were entered into Microsoft Excel spreadsheets, allowing the feeding scans to be isolated for analysis.

Data Analysis

The data was cleaned to standardise plant names, with the knowledge of field assistants and literature, primarily The Preferred Check-list of Sabah Trees (Lee, 2003). Most plants were fully identified in the field; however some could only be identified to the level of genera or in some cases, family. Some plants could only be identified using a local name. As a result, food items are grouped into genera and analysed at this level. Food items identifiable by family only were included in the analysis (e.g. Unknown – Araceae) and completely unidentifiable items were grouped as 'Unknown' and removed from statistical analysis as this category contained multiple genera and would unfairly weight results involving proportional data. Insects were classified as either 'Termites' or 'Insects', which included all other invertebrates consumed. Genera used for the diversity and composition analyses were reduced to include only those that were present in at least 10% of combinations of individual, month and year, which from this point will be referred to as 'individual units'. Individual units with less than two hours of recorded data (40 scans) were also removed. The relative feeding counts (number of scans/total number of scans for the individual unit) were worked out and the resulting proportional data used to identify the key plant genera consumed by orang-utans.

Diversity

To look at the effect of seasonal and inter-year variation in diversity of food items consumed mean diversity was plotted for each month and for each year. In this report, diversity is defined as the number of food items per unit time to overcome problems presented by different amounts of data having been collected in each month. Some months have consistently more data than others; during the wet season, for example, the study site is often flooded, making it difficult to collect data. A mixed effects model was used to test the significance of seasonal and yearly variation in diversity.

Composition

Frequency histograms were made from the relative feeding counts to show the distribution of the proportions of genera that compose the diet. These were constructed for the dry season, the wet season and the entire year. In this study the dry season runs between months 3 and 11 and the wet season occurs during months 12, 1 and 2.

A principle components analysis (PCA) was undertaken to identify major components of the diet. Both a covariance and a correlation analysis, which reduces the effects of differences in feeding efficiencies, were conducted. The covariance analysis was chosen to continue the other analyses. The PCA was used to explain the major variances in the data set. A mixed effects model tested the significance in composition throughout the year and between years. PC1 of the covariance PCA was used as the measure of composition in this model.

The proportions of the ten most consumed items were plotted against month using a stacked area graph to show seasonal variation in the most important parts of the diet. This was then used in conjunction with a graph plotting the first and second axes (PC1 and PC2) against month to draw conclusions and aid interpretation of the principal components analysis. The proportion of major plant parts (fruit, leaves and bark) eaten was also plotted against month to further illustrate seasonal variation in diet composition.

Results

Dietary Overview

- 158 food items were originally recorded in the observational data, 116 of which were identifiable as known food items. Unknown items were combined into the category 'unknown'. 40 genera were present in at least 10% individual units and it was these genera that were used for further analysis. A full list of identified species can be found in Appendix 4.

- 11787 hours of raw data were collected, of which 3811 were feeding behaviour, which consisted of 76229 scans recorded from 33 individual animals. For analysis, only individual units with a minimum of 40 scans (2 hours) were used; this totalled 14 individual orang-utans. 151 individual units were used and 42 units were discarded.

- Ten genera each contributed to more than 2% of the data set, totalling 39539 scans. Because these ten genera made up over half of the data set (52%), they were identified as the ten major dietary components. The remaining 48% of the diet was composed of 107 genera categories.

Seasonal Variation in Diversity of the Diet

- A plot of mean diversity within the year shows that diversity is lowest during month 7, during the later part of the dry season, and immediately preceding the wet season in months 10 and 11.

Major Components of the Diet

Genus	Species (if known)	Local Name	Family
1. *Ficus*	*Ficus sp.*	Kayu Ara	Moracceae
2. *Dracontomelon*	*Dracontomelon dao*	Sengkuang	Anacardiaceae
3. *Diospyros*	*Diospyros sp.*	Kayu Malam	Ebenaceae
4. *Spatholobus*	*Spatholobus hirsutus*	Ramus	Fabaceae
5. *Eugenia*	*Eugenia sp.*	Obah	Myrtaceae
6. *Sandoricum*	*Sandoricum koetjape*	Sentul Hutan	Meliaceae
7. *Bridelia*	*Bridelia sp.*	Akar Garak	Euphorbiaceae
8. *Lophopyxis*	*Lophopyxis maingayi*	Akar	Lophopyxidaceae
9. *Neolamarckia*	*Neolamarckia cadamba*	Laran	Rubiaceae
10. *Mallotus*	*Mallotus sp.*	Mallotus	Euphorbiaceae

Table 1. The ten most consumed genera and their proportion of the diet.

Intra-year Changes in Diversity

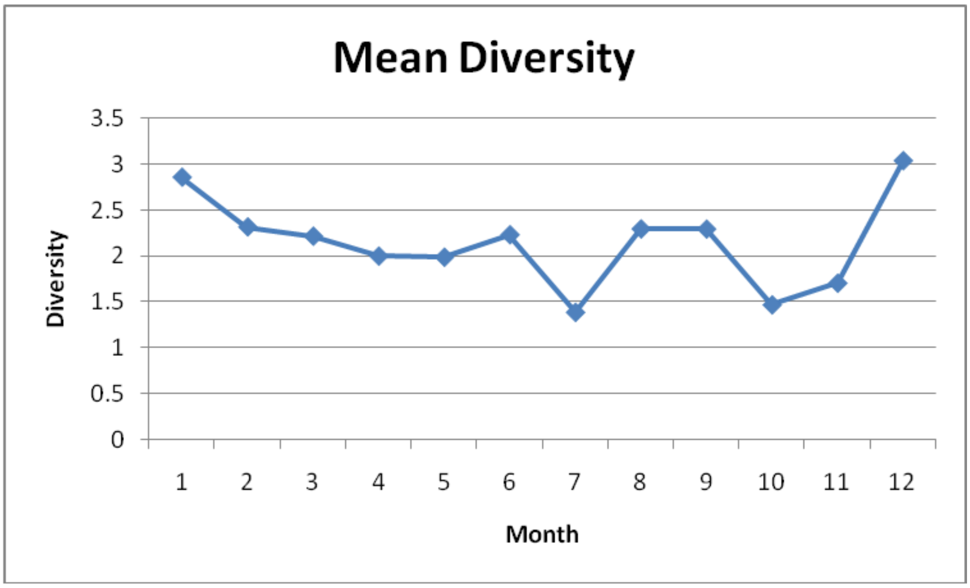


Figure 3. A line graph showing the average diversity rate calculated for each month.

- A mixed effects model was applied to test the significance of variation in diversity (food items eaten per unit time) within and between years. The smooth term, testing for variation within years was not significant (P = 0.26), whilst the year terms were (Appendix 1), indicating no significant variation within the year but variation between years. The P value for 2003 was less significant at P = 0.06.

- A plot of diversity between years shows that following each year with a low diversity value (e.g. 2005 = 1.20) the diversity rises in the following year (e.g. 2006 = 2.04).

Inter-year Changes in Diversity

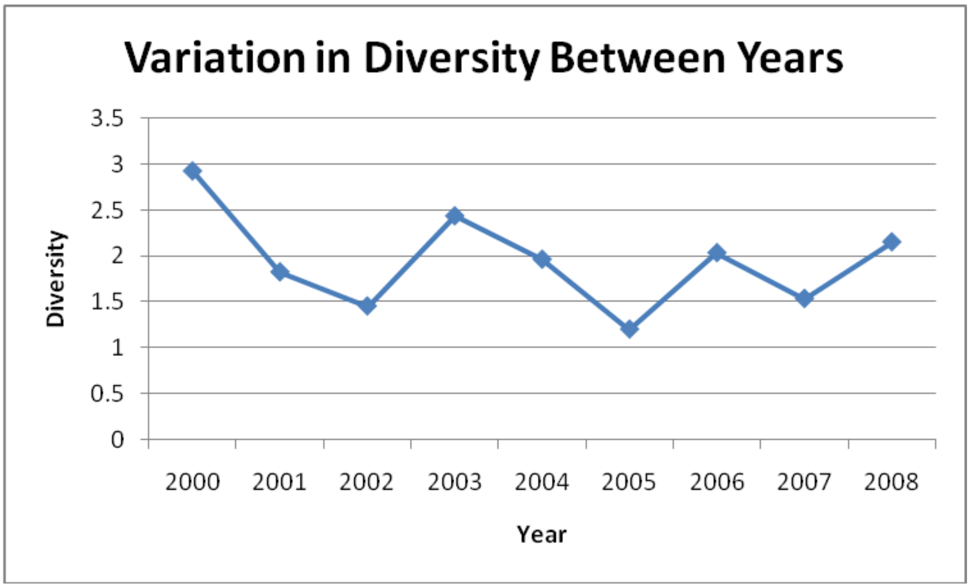
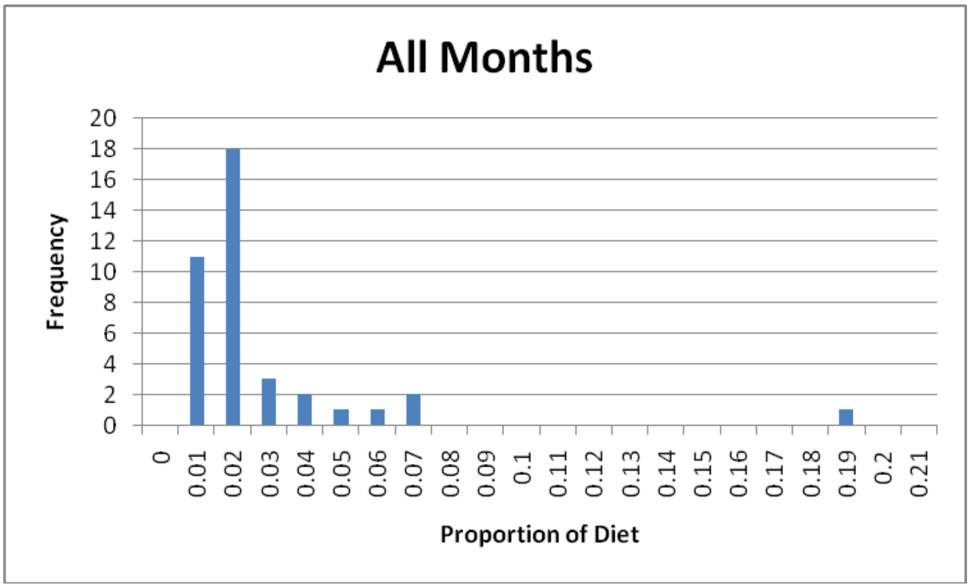


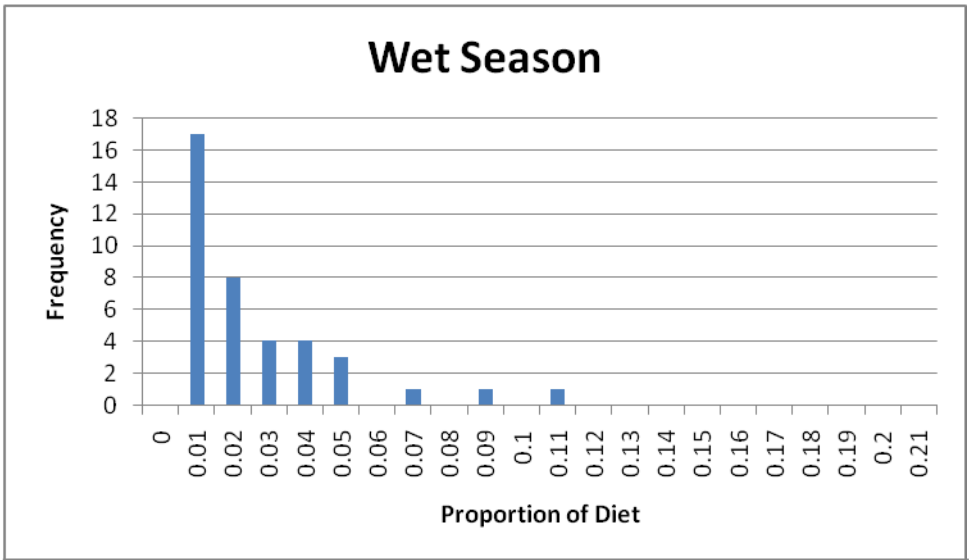
Figure 4. A graph to show the variation in diversity between years. Slight variation is visible in 2003.

Seasonal Variation in Composition of the Diet

- Frequency Histograms: The frequency histograms use proportional data for the genera that were recorded in at least 10% of the individual units. Many genera account for a low proportion of the diet. *Ficus* accounts for the largest proportion, 19%, of the overall diet. The histograms show differences in the diet composition between the wet season (December – February) and the dry season (March-November). *Ficus* accounts for the 21% of the diet in the dry season and 11% in the wet season.

Proportional Distribution of Food Items





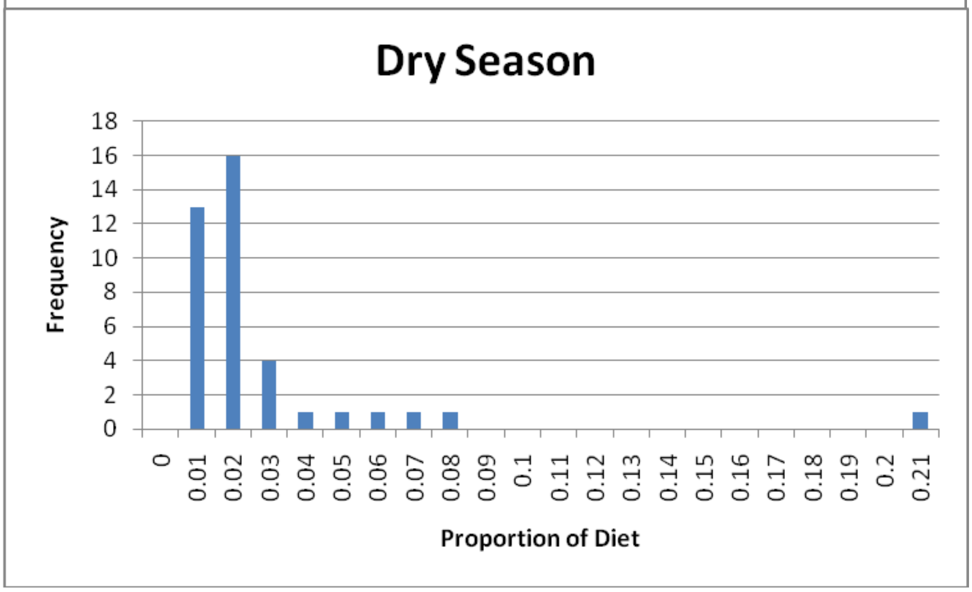


Figure 5. Frequency histograms showing the distribution of recorded genera by proportion. During both the wet and dry seasons there are many genera representing a small proportion of the diet and only a few making up larger parts of the diet.

Covariance PCA Biplot

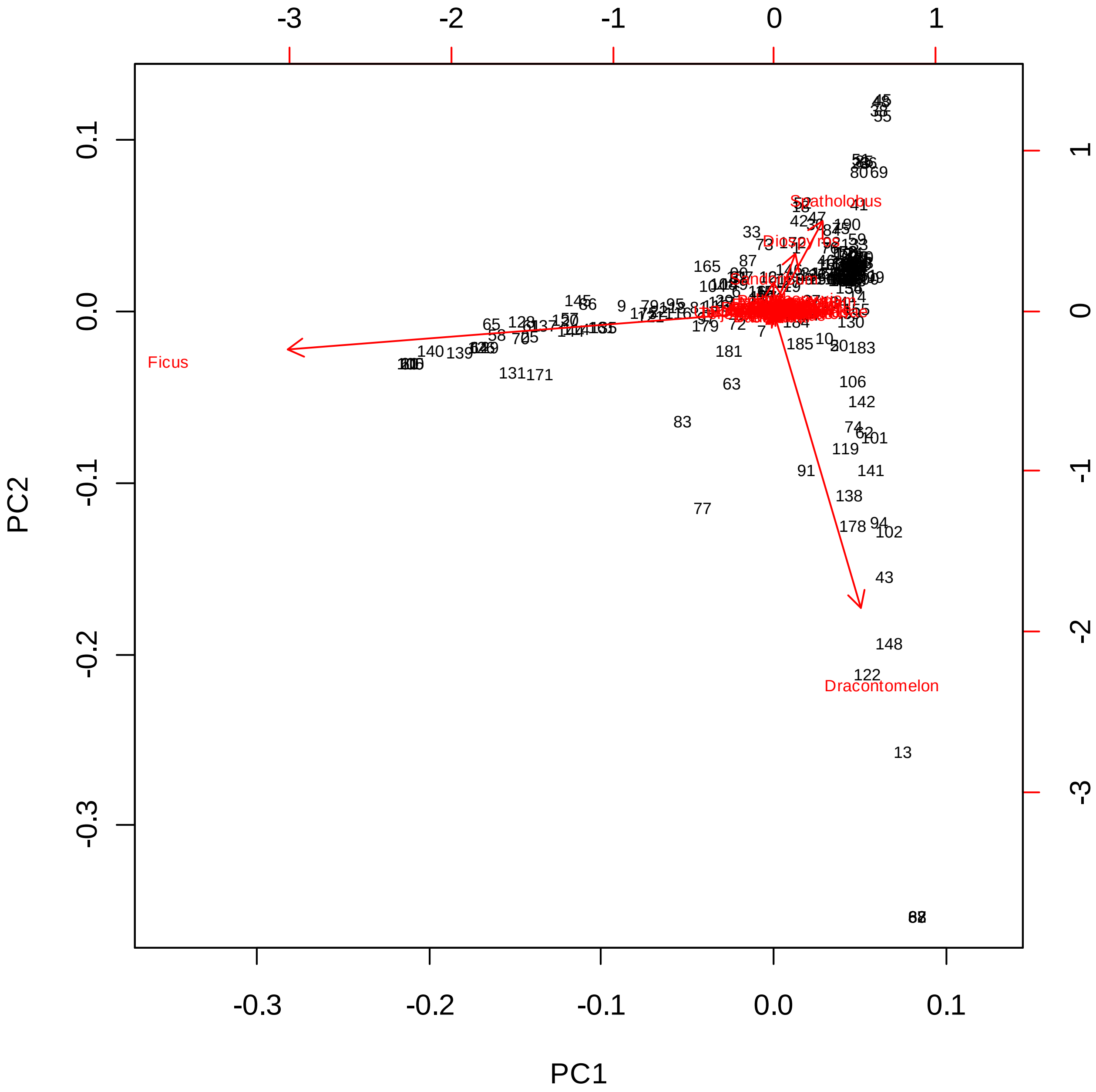


Figure 6. The biplot generated during the principal components analysis shows that *Ficus* loads heavily on PC1, highlighting it as a significant part of the diet.

- The first PC axis, PC1, of the covariance principal components analysis highlights *Ficus* as a significant part of the diet. PC1 describes *Ficus*, which has a large negative loading, and a few genera with a large positive loading on PC1. PC1 explains 24% variance in diet composition. 10% variance is explained by PC2 .

- A mixed effects model was applied to test the significance of variation in diet composition (PC1 covariance analysis) within and between years. The smooth term, testing for variation within years, was highly significant (P=0.00), showing significant variation within the year. The year terms were not significant (Appendix 2) apart from the value for 2003 (P=0.05) which was slightly significant, indicating a small amount of variation in this year.

- A stacked area graph was constructed to show the main differences in intra-year variation in diet composition. *Spatholobus*, *Lopophyxis* and *Bridelia* were grouped together as ‘climbers’ and plotted amongst the ten most consumed genera. Ficus consumption is at its lowest in month 5. At this time *Diospyros* and climber consumption are at their highest. In months 1 and 12, both *Ficus* and climber consumption are low and *Neolamarckia* consumption is high. The graph showing change in PC1 and PC2 throughout the year also shows *Ficus* consumption to drop in month 5, as *Ficus* has a negative loading on the first axis and PC1 has a positive value at this point. The plant part graph (Figure 9) shows plant part proportions throughout the year to be consistent, apart from a reduction in fruit consumption in months 3 to 5 and a slight reduction in month 11. The proportion of leaf and bark consumption increased when fruit consumption decreased.

Change in PC1 and PC2 Throughout the Year

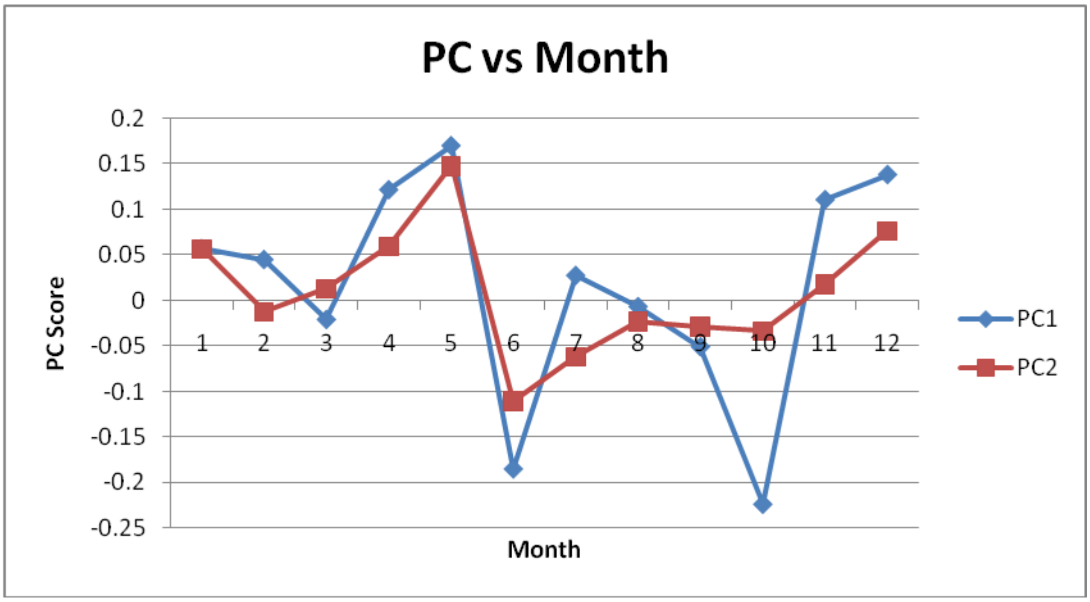


Figure 7. Dietary shifts illustrated by intra-year changes in the first two axes of the principal components analysis.

Intra-year Changes in Diet Composition

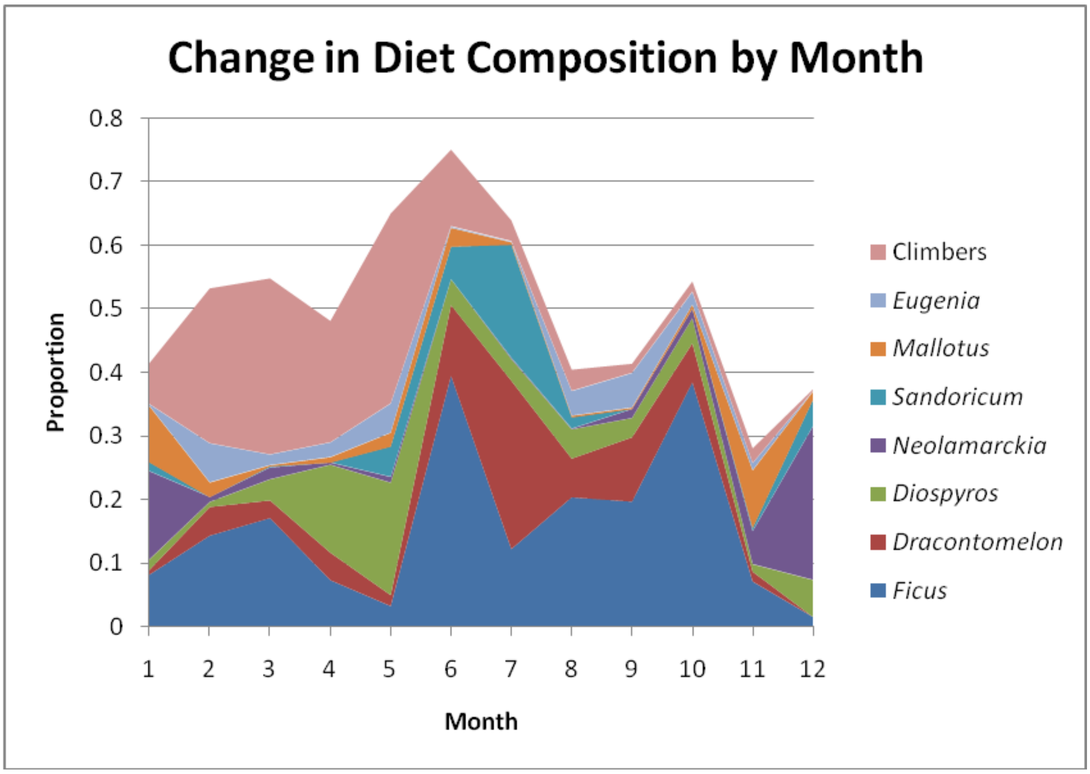


Figure 8. A stacked area graph to show the change in proportions of major components consumed in the diet. The shape created by *Ficus* is almost identical

as that made by the plot of PC1 in Figure 7. When *Ficus* consumption is low, other genera are consumed to take its place.

Parts Eaten Throughout the Year

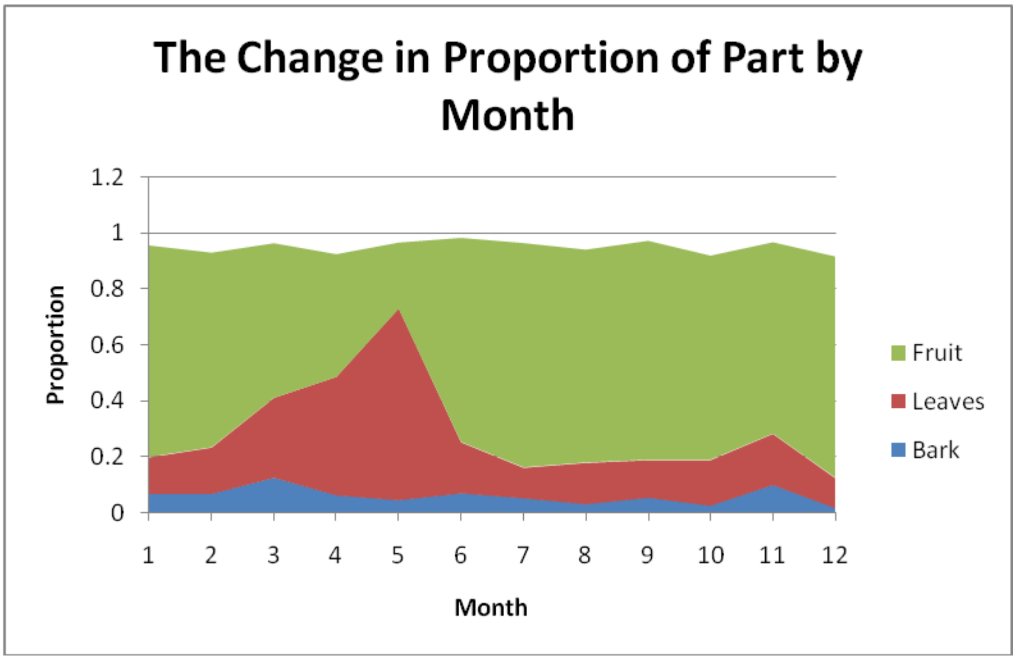


Figure 9. Leaf consumption peaks at month 5, as does *Ficus* consumption (Figure 7). Apart from this peak, the proportion of fruit, leaves and bark in the diet remains similar throughout the year. Fruits constituted the largest part of the diet (69.18%), followed by leaves (20.12%).

Plant Parts Consumed

Part	Number of Recorded Scans	Percentage of Diet (2 d.p.)
Bark	4581	6.01
Fruit	52732	69.18
Leaves	15334	20.12
Other	3581	4.70

Table 2. Proportions and percentages of plant parts that compose the orang-utan diet. Fruits are consumed more than any other part.

Discussion

Overview

Of the 33 animals studied, only 14 were used. It was decided that individual units with less than two hours of data would not be used. This reduced the number of individual orang-utans involved in the study as non-habituated orang-utans passing through the study site are easily disturbed. Disturbed orang-utans have a tendency to flee or change their behaviour, often resting for longer periods of time than usual, which reduces the amount of time spent feeding, and therefore the amount of data collected. Habituated orang-utans are often seen in the study site, and much of the data set was collected from regularly observed orang-utans that are not evidently disturbed by human observation.

The orang-utan diet is made up of a large range of food items. The ten most commonly consumed genera made up 52% of the diet. 107 known genera made up the other half of the diet, which shows the diet of the orang-utan in the Kinabatangan to be widely and thinly spread over a large variety of plant genera. Although the diet consisted mainly of plant items, non-plant items were also recorded. The most commonly consumed non-plant items were insects and water. The food list compiled by Russon *et al.* (2009) also included vertebrate food items such as slow loris and gibbons. Orang-utans at the Kinabatangan site have not yet been observed to eat other primates, but their absence from these results does not mean that orang-utans avoid feeding on vertebrates in Sabah. It is not possible to continually follow all orang-utans in the area, and so events such as these could be missed and the data set is not completely reliable. However, the large size of the data set and length of the study give reliability to the results in comparison with that of a short-term study with fewer observations.

Diversity

No significant variation in diversity was recorded within years, indicating that the different conditions presented by the wet and dry seasons have no marked effect on the amount of food items eaten per unit time. The variation in diversity between years could be attributed to fluctuations in fruit availability as diversity is lowest at the end of the dry season and immediately preceding the onset of the wet season. In 2000, there was a mass fruiting event for *Lithocarpus* and orang-utans were observed to eat large amounts of acorns from this genus (*pers. comm.* Marc Ancrenaz), which could explain, in part, the variation in diversity for the year 2000.

A mixed effects model was used to look at the patterns in diversity and composition. This kind of multilevel model is useful when dealing with data collected from multiple individuals as it works with patterns rather than absolute amounts. This reduces problems caused by individual orang-utan differences in feeding preferences by averaging the trends for each individual so that the pattern alone may be studied.

Composition

The frequency histograms show that many genera contribute to a low proportion of the diet. During the dry season *Ficus* accounts for the highest proportion of the diet (over 20%) whereas in the wet season it accounts for less. The difference in contribution to the diet between *Ficus* (11%) and the next largest contributors is reduced in the wet season, with *Neolamarckia* (9%) and *Bridelia* (7%), a woody climber, also playing an important part of the diet at this time of year.

A principal components analysis (PCA) was chosen to explain the variance in diet composition throughout the year. The PCA was originally conducted in two different ways: analysis of the correlation matrix and analysis of the covariance matrix. The correlation matrix analysis standardises the data so that the genera have similar variabilities. This means that *Ficus*, the major component of the diet, is down-weighted in order to show other patterns in the data set and dietary shifts involving the more minor components that could be overlooked due to the presence of Ficus. By standardising the data, this approach also reduces the effects of differences in feeding efficiencies. However, the covariance analysis was chosen for use in this study as it clearly identifies Ficus as the dominant food item and allows a closer look at how *Ficus* consumption relates to other areas of the diet.

The mixed effects model showed seasonality of diet composition throughout the year, but no significant variation between years. 2000 was a mass fruiting year for *Lithocarpus* and the orang-utans were observed to be eating large quantities of acorns from this plant (*pers. comm.* Marc Ancrenaz), but it does not appear to have affected the overall feeding habits for the year.

The PCA biplot shows that *Ficus* and *Dracontomelon* are important components of PC1. *Ficus* has a heavy negative loading on this axis and *Dracontomelon* has a positive loading. This indicates that when *Ficus* is absent from the diet *Dracontomelon* is an important food item used to fill in. *Dracontomelon* was shown to be the genera that contributes overall to the second highest proportion of the diet (6.5%). *Spatholobus* and *Eugenia* are also present in the diet when *Dracontomelon* is eaten, as these genera also have a positive loading on PC1. *Diospyros* also contributed to a large proportion of the diet (6%) and has a positive loading on the second axis, PC2, along with *Spatholobus* and *Sandoricum*. These are food items consumed when *Ficus* and *Dracontomelon*, which have a negative loading on PC2, are eaten less. These six genera (*Ficus, Dracontomelon, Spatholobus, Diospyros, Sandoricum* and *Eugenia*) were identified as the genera that contributed to the highest proportions of the diet.

Three graphs were included to focus on the intra-year variation. Figure 7 shows major trends in dietary shifts on PC1 and PC2 throughout the year, showing shifts between genera that load heavily on the first two PC axes and therefore contribute to a substantial part of the diet. The most consumed genera were the focus of the stacked area graph (Figure 8) as they contribute to such a large part of the diet (52%). *Spatholobus, Lophopyxis* and *Bridelia* were grouped together as 'climbers' as due to their similar structure they fill a similar niche in the community. *Bridelia* is known to fruit once a year, at the beginning of the dry season, and this can be seen in the original graph (Appendix 3) where the climbers are left to be represented as three separate genera.

Ficus consumption rose sharply towards the middle of the dry season and peaked again in month 10, at the end of the dry season (PC1 series, Figure 7). When *Ficus* consumption decreased, it was mainly replaced by *Dracontomelon*, the woody climbers and *Sandoricum* (Figure 8). *Sandoricum* and *Dracontomelon* were at their highest consumption during month 7, when *Ficus* was again at a low point. *Ficus* was at its lowest consumption level in month 5 (Figures 7 and 8). During this month, fruit consumption was also at its lowest and leaf consumption at its highest point (Figure 9). The climbers and *Diospyros* were the major replacement food sources at this time. From this it is possible to identify that fruits are the most desirable plant part to be obtained from *Ficus*. Conversely, it appears that leaves are favoured by orang-utans when

Diospyros and the climbers are eaten. Fruits were found to be the most consumed plant part, followed by leaves and then bark (Table 2).

Orang-utans in the Kinabatangan manage to maintain a high level of fruits in their diet throughout the year, despite seasonal fluctuations in diet composition. Certain trees fruit only once annually which allow for orang-utans to 'top up' on fruits when their usual food supplies are lower. The woody climbers are important fall-back foods, for example *Bridelia* fruit at the beginning of the year (*pers. comm.* Marc Ancrenaz) during the wet season when consumption of *Ficus* is low. Although fruits are the preferred plant part, orang-utans may still opt to supplement their diet with other food types even if good quality fruits were consistently available in large quantities. For many primates, fruits provide for the bulk of their energy requirements (Strier, 2006) but may not be able to supply vitamins and minerals obtained from food eaten opportunistically, for example from insects.

From this study it appears that orang-utans consume fruits in large quantities when available, shifting their diet towards less preferred food sources when necessary. Availability of food sources influences both the composition and diversity of the diet and without abundance details of food items it is difficult to draw strong conclusions about dietary choices. Wich *et al.* (2006) concluded that orang-utans in Ketambe feed on *Ficus* when other preferred food items are not available, but it is not possible to determine whether this explains Kinabatangan orang-utan feeding choices, or whether they turn to other food items when *Ficus* is not available. Where possible, further investigation should include food availability data for the area. In 2007, it was found that orang-utan abundance at the study site fluctuated in a positive correlation with *Ficus* abundance. The population declined during the wet season and the hottest months of May and June. (Ancrenaz *et al.*, 2007). The reduction in orang-utan abundance at these times in 2007 and the decline in *Ficus* during months 5, 11, 12 and 1, shown by the intra-year patterns highlighted in this study, support the suggestion that *Ficus* is a preferred food source and that other genera are used to fall back on as subsistence foods.

In addition to their importance in nutrition, plants also play an integral role in resting, nesting, shelter provision, passage for movement and self-medication. 80 tree genera used as nesting sites were found in a study of orang-utans in Sabah (Ancrenaz *et al.*, 2003). Morrogh-Bernard (2008) states that whilst no species of the genus *Commelina* has been recorded as an orang-utan food item, it has been recorded in fur-rubbing actions which could have an antibacterial role. Diet composition can therefore lead to suggestions as to the most important plants for sustaining an orang-utan population, but other factors should not be overlooked.

Procedure and Limitations

Data from 1999 were not included in the analyses as methods were changed slightly between 1999 and 2000. Prior to 2000, scans were taken at 5 minute intervals, instead of every 3 minutes as used in the rest of the study. Many of the field staff were also less experienced at data collection during the first year of the study and, as a result, more feeding scans were placed in the 'unknown' category than in other years. The most commonly consumed plants were also recorded in higher quantities and it is possible that more unusual and less frequently encountered plants were mistaken for more familiar plants. On these grounds, data were not included from this year, with the intention of working with a more reliable data set.

Identification of plant species in the field presents several problems, all of which lead to questions about the reliability of data recorded. Staff at the field site undergo extensive training to aid recognition of food items in the field, and plant species are identified by comparison of morphological features (leaf shape and arrangement, colour and texture of bark, structure of fruit or seeds), studying fallen branches, fruits, seeds and examining exudates. Factors that can confound plant identification include the height at which the animal is feeding, which can make identification between similar species very difficult, and adverse weather conditions. Poor weather conditions often present another problem; orang-utans were often observed hiding or sheltering from heavy rain, during which it is easy to lose sight of the focal animal. Sound is important in detecting and following wild orang-utans and rain makes it very difficult to locate orang-utans to follow.

It was decided to use the genera level for all analyses because many records in the raw data set only identify the food items to genera or family level, so to work at species level would be inaccurate as ambiguous observations could fall into both the species and genera category. Most genera recorded in the diet cover only one or two species, whereas grouping together food items by family would cover multiple species in each category. Using genera, where possible, increases the validity of the results by standardising the level of identification whilst avoiding oversimplifying the investigation by generalising to family level.

Future Work and Implications

As with many mammals, male and female orang-utans have different energy requirements and therefore have corresponding differences in feeding habits; female orang-utans, for example, must produce milk for offspring and provide nourishment for the foetus when expecting a baby. The quality of milk produced by lactating female primates is diet-dependent and females with high energy diets have been found to reproduce at an earlier age (Strier, 2006). This is particularly important for orang-utans as a slow reproducing animal with the longest primate inter-birth interval of between 84-96 months (Strier, 2006). Male orang-utans are divided further into two forms: the flanged male and the unflanged male. Flanged males produce long-calls, are larger than their unflanged counterparts and bear characteristic cheek flanges, the development of which may use more energy than an unflanged equivalent. Unflanged males have been observed to spend more time moving than the flanged males, which are fonder of resting. These factors, and others that have not been considered here, are likely to influence the feeding behaviour of orang-utans. Although preliminary tests were undertaken to identify differences between the three sex classes, it was not possible to enter into this area in depth in addition to the work carried out in this project. Further work could incorporate hypotheses such as ‘There is a significant difference in dietary composition between orang-utan sex classes’ and ‘There is a significant difference in dietary diversity between orang-utan sex classes’. Comparisons could also be made with existing data from other populations of *Pongo pygmaeus morio* to test for differences between populations. The quality and type of forest differs enormously from one site to another across Borneo (Russon *et al.*, 2009), therefore it would be expected that orang-utan diets would change accordingly. However, the different study lengths would have to be addressed; the study in the Kinabatangan is an ongoing, long-term project, and with the exception of two sites, has the longest duration of any current study of orang-utan feeding behaviour. Russon *et al.* (2009) found problems when comparing studies of different lengths, as short-term studies had a tendency to under-estimate the number of food items consumed.

Conclusions

- *Ficus*, the most commonly consumed item, is the keystone species for this population and is integral in the long-term viability of orang-utans in the Kinabatangan.
- The effects of seasonality were witnessed in diet composition but have little effect on diet diversity.
- Some inter-year variation was found in diet diversity but not in composition, which indicates that whilst there may be some differences in the number of food items eaten per unit time between years, the feeding preferences remain consistent.
- Although some key tree species can be identified as particularly important to protect for orang-utan conservation, the Kinabatangan population relies on a large range of food items. The diet is widely and thinly spread, and despite the area being secondary forest, it manages to sustain a high density of orang-utans.

Acknowledgements

My thanks go to the KOCP field assistants for allowing us to work with them in the forest, especially to Mislin Elahan, Azman Sakong, Azli Etin, Herman Suali, Adyt and Zul with whom we worked most closely. Many thanks also to Dr. Marc Ancrenaz for letting us ‘play with his data’, to Dr. Benoit Goossens for all of his support throughout the year, to Dr. Ian Vaughan for aiding never-ending statistics queries, to Harjinder Kler for technical and moral support, to Zainal Abidin Ja’afar for all of his help at Danau Girang Field Centre, to Harizah, Samsudin and their family for looking after us in Sukau, to Nurzafarina Othman and Rachel Munds for their good advice, and to everyone in Sabah who made us feel so welcome during our professional training year. Thanks also to Chloe Parker, without whom I would still be cleaning the raw data set, and possibly lost in the jungle.

<u>References</u>

Ancrenaz, M. *et al.* (2007). *Activity Report 2007: Kinabatangan Orang-utan Conservation Project.* Hutan Publications, Kota Kinabalu, Sabah, Malaysia.

Ancrenaz, M. *et al*. (2006). *Activity Report 2006: Kinabatangan Orang-utan Conservation Project*, p14, Hutan Publications, Kota Kinabalu, Sabah, Malaysia.

Ancrenaz, M., Calaque, R. And Lackman-Ancrenaz, I. (2003). Orang-utan nesting behaviour in disturbed forest of Sabah, Malaysia: Implications for nest census. *International Journal of Primatology,* **25**, 5: 983-1000

Ancrenaz, M., Goossens, B., Gimenez, O., Sawang, A. and Lackman-Ancrenaz, I. (2004). Determination of ape distribution and population size using ground and aerial surveys: A case study with orang-utans in Lower Kinabatangan, Sabah, Malaysia. *Animal Conservation,* **7**: 357-385.

Delgado. R.A. and van Schaik, C.P. (2000). The behavioural ecology and conservation of the orang-utan (*Pongo pygmaeus)*: A tale of two islands. *Evolutionary Anthropology,* **201**, 9: 201-218.

Knott, C.D. (1998). Changes in orang-utan diet, caloric intake and ketones in response to fluctuating fruit availability. *International Journal of Primatology,* **19**, 1061-79.

Lackman, I. and Ancrenaz, M. (2008). *Hutan orang-utan conservation activities in 2008.* Hutan Publications, Kota Kinabalu, Sabah, Malaysia.

Lee, Y.F. (2003). *Preferred Check-List of Sabah Trees.* 3rd Edition. Natural History Publications (Borneo) Sdn.Bhd, Malaysia.

Marshall, A.J., Ancrenaz, M., Brearley, F.Q., Fredriksson, G.M., Ghaffar, N., Heydon, M., Husson, S., Leighton, M., McConkey, K.R., Morrogh-Bernard, H.C., Proctor, J., van Schaik, C.P., Yeager, C.P., Wich, S.A. (2009). The Effects of Forest Phenology and Floristics on Populations of Bornean Orangutans. In: *Orangutans: Geographic Variation in Behavioural Ecology and Conservation.* Oxford University Press, USA (eds. Wich, S.A., Utami-Atmoko, A.A., Setia, T.M., van Schaik, C.P.), pp. 135-155.

Morrogh-Bernard, H.C. (2008). Fur-rubbing as a form of self-medication in *Pongo pygmaeus. International Journal of Primatology,* 29: 1059-1064.

Morrogh-Bernard, H.C., Husson, S. and McLardy, C. (2002). Orang-utan Data Collection Standardisation. *Orang-utan Culture Workshop,* U.S.A.

Prasetyo, D., Ancrenaz, M., Morrogh-Bernard, H.C., Utami-Atmoko, S.S., Wich, S.A. and van Schaik, C.P. (2009). Nest Building in Orang-utans. In: *Orangutans: Geographic Variation in Behavioural Ecology and Conservation*. Oxford University Press, USA (eds. Wich, S.A., Utami-Atmoko, A.A., Setia, T.M., van Schaik, C.P.), pp. 269-277.

Rijksen, H.D. and Mijaard, E. (1999). *Our Vanishing Relative: The Status of Wild Orang-utans at the Close of the Twentieth Century.* Kluwer, Dordrecht.

Russon, A.E., Wich, S.A., Ancrenaz, M., Kanamori, T., Knott, C.D., Kuze, N., Morrogh-Bernard, H.C., Pratje, P., Ramlee, H., Rodman, P., Sawang, A., Sidiyasa, K., Singleton, I. and van Schaik, C.P. (2009). Geographic Variation in Orang-utan Diets. In: *Orangutans: Geographic Variation in Behavioural Ecology and Conservation.* Oxford University Press, USA (eds. Wich, S.A., Utami-Atmoko, A.A., Setia, T.M., van Schaik, C.P.), pp. 135-155.

Strier. K.B. (2006). *Primate Behavioural Ecology.* 3rd Edition. Prentice Hall, Boston, U.S.A.

Wich, S.A., Meijaard, E., Marshall, A.J., Husson, S., Ancrenaz, M., Lacy, R.C., vanSchaik, C.P., Sugardjito, J., Simorangkir, T., Traylor-Holzer, K., Doughty, M., Supriatna, J., Dennis, R., Gumal, M., Knott, C.D. and Singleton, I. (2008). Distribution and conservation status of the orang-utan (*Pongo* spp.) on Borneo and Sumatra: How many remain? *Oryx*, **42**, 3: 329-339.

Wich. S.A., Utami-Atmoko, S.S., Setia, T.M., Djoyosudharmo, S. and Geurts, M.L. (2006). Dietary and energetic responses of *Pongo abelii* to fruit availability fluctuations. *International Journal of Primatology,* **27**, 6: 1535-1550.

Appendices

Appendix 1: Diversity Variation Between Years

Year	Pr(>|t|)
2000	8.44e-16
2001	0.00283
2002	6.78e-05
2003	0.06126
2004	0.00515
2005	0.04842
2006	0.02884
2007	0.00102
2008	0.00108

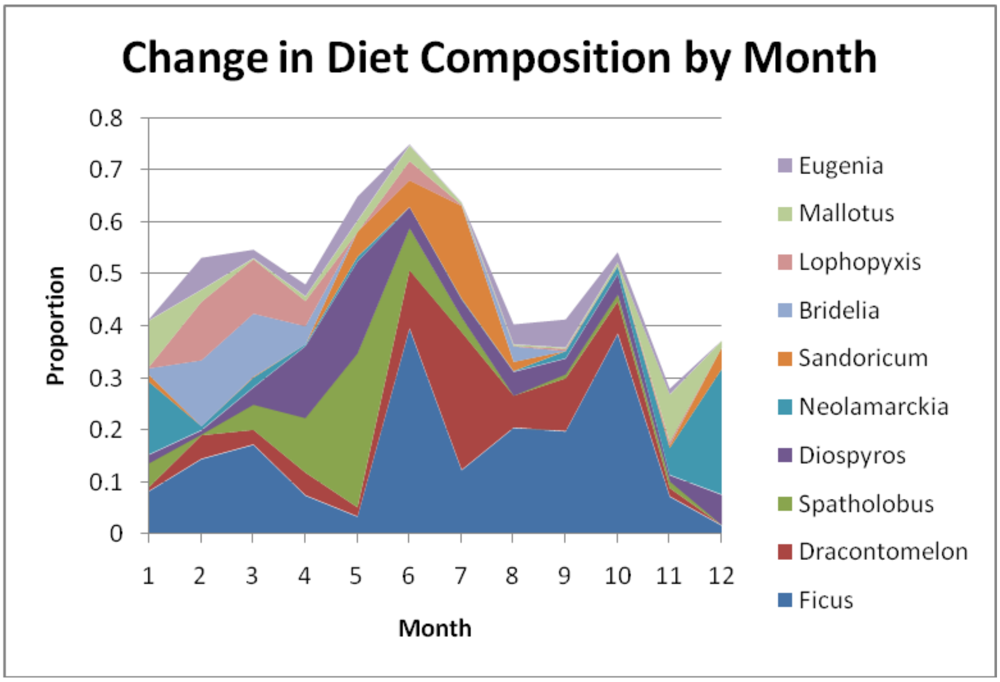
P values: Diversity variation between years, mixed effects model.

Appendix 2: Composition Variation Between Years

Year	Pr(>|t|)
2000	0.7915
2001	0.5347
2002	0.3262
2003	0.0513
2004	0.9832
2005	0.7150
2006	0.1890
2007	0.2811
2008	0.4108

P values: Composition variation between years, mixed effects model.

Appendix 3: Stacked Area Graph to Show Change in Diet Composition



Appendix 4: Full List of Recorded Food Items

Scientific Name	Local name	Family Name
Celosia sp.	Akar	Amaranthaceae
Buchanania sp.	Kepala tundang	Anacardiaceae
Dracontomelon dao	Sengkuang	Anacardiaceae
Gluta sp.	Rengas	Anacardiaceae
Koordersiodendron pinnatum	Ranggu	Anacardiaceae
Mangifera caesia	Beluno	Anacardiaceae
Mangifera odorata	Mangga	Anacardiaceae
Melanochyla beccariana	Rengas lupi	Anacardiaceae
Parishia insignis	Layang-layang	Anacardiaceae
Pentaspadon motleyi	Pelajau	Anacardiaceae
Semicarpus sp.	Rangas	Anacardiaceae
Artabotrys sp.	Akar	Annonaceae
Cananga odarata	Bunga gadung	Annonaceae
Polyalthia sp.	Pisang-pisang	Annonaceae
Uvaria sp.	Pisang-pisang	Anonnaceae
Alstonia sp.	Pulai	Apocynaceae
Tabernaemontana macrocarpa	Burut-burut	Apocynaceae
Willughbeia sp.	Serapid	Apocynaceae
Sca/indapsus sp.	Vine	Araceae
Asplenium sp.	Tapako	Aspleniaceae
Durio grandiflorus	Durian Hantu	Bombacaceae
Durio griffithii	Durian Kuning	Bombacaceae
Durio sp.	Durian	Bombacaceae

Canarium sp.	Kedondong	Burseraceae
Dacryodes sp.	Kedondong	Burseraceae
Lophopetalum sp.	Perupok	Celastraceae
Maranthes corymbosa	Bangkawang	Chrysobalanaceae
Maranthes sp.	Bangkawang	Chrysobalanaceae
Parinari oblongifolia	Merbatu	Chrysobalanaceae
Merremia sp.	Akar	Convolvulaceae
Dillenia excelsa	Simpoh Laki	Dilleniaceae
Dipterocarpus sp.	Keruing	Dipterocarpaceae
Dryobalanops sp.	Kapur	Dipterocarpaceae
Hopea Nervosa King	Selangan Jangkang	Dipterocarpaceae
Shorea sp.	Seraya/Selangan jangkang	Dipterocarpaceae
Vatica sp.	Resak	Dipterocarpaceae
Diospyros sp.	Kayu malam	Ebenaceae
Elaeocarpus sp.	Kungkurad	Elaeocarpaceae
Erythroxylum cuneatum	Perapat burung	Erythroxylaceae
Antidesma sp.	Medang	Euphorbiaceae
Aporusa sp.	Bagil	Euphorbiaceae
Baccaurea parviflora	Kunau-kunau	Euphorbiaceae
Bridelia sp.	Akar garak	Euphorbiaceae
Cleistanthus megacarpus	Baubo	Euphorbiaceae
Croton sp.	Croton/kapas-kapas	Euphorbiaceae
Excoecaria indica	Apid-apid	Euphorbiaceae
Glochidion borneensis	Obah nasi	Euphorbiaceae
Homalanthus populneus	Ludai susu	Euphorbiaceae
Macaranga sp.	Sedaman	Euphorbiaceae
Mallotus sp.	Mallotus	Euphorbiaceae
Paracroton sp.	Gagil	Euphorbiaceae
Entada rheedii	Bantal pipit	Fabaceae/Leguminosae
Dalbergia sp.	Serapit	Fabaceae/Papilioniodeae
Lithocarpus sp.	Mempening	Fagaceae
Hydnocarpus borneensis	Karpus	Flacourtiaceae
Hydnocarpus sp. (woodii)	Karpus	Flacourtiaceae
Gnetum sp.	Akar	Gnetaceae
Calophyllum obliquinervium	Bintangor	Guttiferae
Garcinia parvifolia	Kandis	Guttiferae
Cratoxylum sp.	Geronggang	Hypericaceae
Eusideroxylon zwagerii	Belian	Lauraceae
Knema sp.	Darah-darah	Lauraceae
Litsea sp.	Medang	Lauraceae
Barringtonia sp. (macrostachya)	Tampalang	Lecythidaceae
Planchonia vanlida	Putat paya	Lecythidaceae
Sindora beccariana	Sepetir	Leguminoceae
Bauhinia sp.	Tapak Kerbau	Leguminosae

Millettia sp.	Kudang	Leguminosae
Parkia sp.	Kupang	Leguminosae
Sindora sp.	Sepetir	Leguminosae
Strythnos sp.	Akar Bena	Leguminosae
Koompassia excelsa	Mengaris	Leguminosae/Caesalpinoideae
Lophopyxis maingayi	Akar	Lophopyxidaceae
Flagalaria sp.	Akar	Malpighiaceae/Flagelleraceae
Pternandra coerulescens	Sirih-sirih	Melastomataceae
Aglaia sp.	Langsat-langsat	Meliaceae
Dysoxylum sp.	Akar	Meliaceae
Lansium domesticum	Langsat	Meliaceae
Sandoricum koetjape	Sentul hutan	Meliaceae
Walsura pinnata	Lentupak Mata Kucing	Meliaceae
Memecylon laevigatum	Nipis kulit	Melostomaeceae
Artocarpus anisophyllus	Terap ikal	Moraceae
Artocarpus elasticus	Terap Togop	Moraceae
Artocarpus sp.	Terap	Moraceae
Ficus sp.	Kayu ara	Moraceae
Ficus sp.	Akar	Moraceae
Prainea limpato	Megah susu	Moraceae
Horsfieldia grandis	Darah-darah	Myristicaceae
Eugenia sp.	Obah	Myrtaceae
Syzgium sp.	Obah	Myrtaceae
Scorodocarpus borneensis	Bawang-bawang	Olacaceae
Chionanthus pluriflorus	Bangkulat	Oleaceae
Calamus sp.	Rotan	Palmae
Pholidocarpus maiadum	Serdang	Palmae
Pandanus sp.	Pandan-pandan	Pandanaceae
Spatholobus hirsutus	Akar	Papilioniodeae
Spatholobus sp.	Ramus	Papilioniodeae
Xanthophyllum ellipticum	Minyak beruk	Polygalaceae
Zizyphus sp.	Monsit	Rhamnaceae
Carallia brachiata	Meransi	Rhizophoraceae
Nauclea sp. (subdita)	Bangkal	Rubiaceae
Neolamarckia cadamba	Laran	Rubiaceae
Syndrica sp.	Kopi-Kopi	Rubiaceae
Uncaria sp.	Akar Nanti Dulu	Rubiaceae
Alangium sp.	Satu inci	Sapindaceae
Dimocarpus longan	Mata kucing	Sapindaceae
Nephelium lappaceum	Rambutan	Sapindaceae
Pometia pinnata	Kasai	Sapindaceae
Ganua sp.	Nyatoh	Sapotaceae
Madhuca sp.	Nyatoh	Sapotaceae
Palaquium sp.	Nyatoh	Sapotaceae

Duabanga moluccana	Magas	Sonneratiaceae
Heritiera simplicifolia	Kembang	Sterculiaceae
Kleinhovia hospita	Timahar	Sterculiaceae
Pterospermum sp.	Bayur	Sterculiaceae
Symplocos fasciculata	Jiak	Symplocaceae
Aquilaria malaccensis	Gaharu	Thymelaeaceae
Pentace laxiflora	Takalis daun Halus	Tiliaceae
Microcos antidesmifolia	Kerodong buluh	Tilliaceae
Microcos crassifolia	Kerodong	Tilliaceae
Gironniera nervosa	Ampas tebu	Ulmaceae
Poikilospermum sp.	Seringkalang	Urticaceae
Teijsmanniodendron sp.	Buak-buak	Verbenaceae
Vitex pinnata	Kulimpapa	Verbenaceae
Vitex pubescens	Kulimpapa	Verbenaceae
Tetrastigma sp.	Akar (Kaum Anggur)	Vitaceae
Ginger sp.	Talidus	Zingiberaceae
Unknown Vine	Duit-duit	Unknown
Colona sp.	Lamba	Tilliaceae
Death Tree!	Kayu Mati	Unknown
Unknown - Kari hutan	Kari hutan	Unknown
Unknown - Talasai jambu	Talasai jambu	Unknown
Vintalago sp.	Akar	Unknown